AMERICAN OPTOMETRIC ASSOCIATION
LECTURES DELIVERED AT THE TWENTY-FIFTH
CONVENTION. 1922

Lectures Delivered at the

Twenty-Fifth Convention

of the

American Optometric Association
Indianapolis, Indiana

June 26th, 27th, and 29th, 1922

"Prescribing of Prisms" — *Charles Sheard, Ph. D.*
"Astigmatism" — *Howard D. Minchin, Ph. D.*
"Presbyopia" — *Dr. William B. Needles*

DEPARTMENT OF EDUCATION
American Optometric Association
Box 1042
Hartford, Connecticut

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Held in St. Louis, Missouri, January 12th and 13th, 1922.

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Editor's Note

At our Convention this year we are trying a new plan of having the three principal lectures printed. Discussion will follow each lecture by three well known educators after which open discussion will be allowed. Pages for notes have been inserted. Prof. Woll's lecture is not included as most of it will be found in his recently published work on the same subject, a work every Optometrist should procure.

WILLIAM S. TODD, *Editor*.

THE PRESCRIBING OF PRISMS

being

The Outline of an Address on this Subject

by

Charles Sheard, Ph. D.
Southbridge, Mass.

A great many practitioners have, in large measure, eliminated the ophthalmic prism and any prescriptions calling for prisms from the catagory of their ocular examinations. This is due largely to the fact, as they state it, that there is no rational basis and no definite criteria to which they may conform and by which they may be guided in their practices. We are desirous, therefore, of endeavoring to point out a rationale of prescribing ophthalmic prisms which may serve as the basis for the intelligent and scientific use of these optical appurtenances.

A Pair of Eyes is a Team

A prism is an optical crutch, just the same as any other ophthalmic accessory which may be prescribed for an eye or pair of eyes. Spheres, cylinders and combinations thereof are prescribed in order that either better vision may be obtained or more comfortable vision accrue to the wearer. In cases of hyperopia and hyperopic astigmatism proper lenses are to be prescribed for the alleviation of innervational functionings of the ciliary muscles or in order to enable the function of accommodation to operate as in an emmetropic eye. Myopic corrections are to be employed in order that distinct distant seeing may be enjoyed and that the ciliary muscles may be called into action to a standard amount when close work is done. All of these corrections are administered for the purpose of giving as *distinct* and *comfortable vision* as possible.

But none of these investigations on refractive errors, which have to do with each eye individually as an organ of vision, have anything to do *per se* with the question as to whether or not binocular single vision is enjoyed, and if such is possible, whether the eyes engage in such singleness of vision with or without comfort. Hence, all of our examinations upon refractive and accommodative defects have to do with comfortable, distinct vision, while all tests upon the function of binocular single

vision have to do with the ability of these two eyes to work in harmony and comfort as a pair or as a team.

It is quite evident, as a simple illustration, that it is possible to buy two individual horses which are perfectly working animals and yet, when hitched together, have a very inefficiently working pair of horses, for one may be much higher than the other, or they may tend to pull away from each other or they may bite at each others necks. As a result of these inabilities to work as a team, such horses demand skillful driving on the part of the teamster. And this teamster must spend many tiresome minutes exerting unnatural pulls upon the reins. In these exertions he must expend energy which would not be demanded if these horses worked together as a well-balanced team.

Just so with a pair of eyes. These may fail to coordinate as a team and therefore demand of the drivers, the nerve centers, undue innervations which, delivered through the extrinsic muscles — which are the reins — cause these eyes to engage in the act of binocular single vision through the expenditure of energy. The expenditure of normal bodily energy always means fatigue, but the expenditure of unnecessary and excessive energy means physical punishment and drained resources. For excesses are strictly tongues of disease.

Every practitioner upon the eyes ought, therefore, to first of all appreciate the fact that the problems pertaining to each eye, in and of itself, are not the only matters of ocular importance needing solution and that the coordination of a pair of eyes in the act of binocular single vision is as important — if not at times a more important — problem than the former.

Liabilities and Resources.

In our work upon the discovery and corrections of refractive anomalies we determine two important factors; namely: (1) liabilities and (2) assets or resources. In a case of presbyopia, for instance, in which we are dealing with accommodative deficiencies, we determine: (1) the necessary amount of accommodation which should be supplied by measuring the distance from the eyes at which close work is demanded; (2) we find whether or not the demand can be met; in advanced presbyopia we know it cannot; (3) we determine the amount of reserve accommodation after supplying any given arbitrary reading correction. These facts tell us: (1) the *liabilities*, (2) whether these liabilities can be met or not met and (3) the *resources* or reserves. As a simple illustration, let us say that we have a case in which O. U. + 1.00 D. S. gives V = 20/20. Let us assume a reading point of 13 inches. This demands an accommodative action of 3 diopters. The liability or bill to be paid therefore, amounts to 3 diopters. If the patient sees detail distinctly at thirteen inches we know that the requisite amount

of accommodation has been supplied. But can it be maintained for a considerable period of time and with comfort? The answer must be found on the basis of the accommodative reserves, either through finding the near-point or through determining in some manner the accommodative amplitudes. If the accommodative reserve is but 1 diopter, then we know that reading at 13 inches cannot be comfortably maintained.

The Binocular Liability

These same fundamental principles hold in our determinations as to whether or not binocular single vision can be obtained and maintained. If the point of fixation is at 20 feet, then we must investigate binocular liabilities and reserves at 20 feet. If the point of fixation is at 13 inches, then our tests upon these binocular liabilities and reserves must be made at that point, since ocular functions and their coordination are not maintained at different fixation points according to any fixed or definite rule but vary with each point chosen.

The *binocular liability* may be ascertained through the use of any testing device, such as the Maddox rod, which permits of the abolition of the act of binocular single vision. When a pair of eyes is equipped with those lenses which, in our judgment, properly minister to the needs of those eyes from the standpoint of distinct vision, we proceed to test these eyes, thus equipped, as to their tendencies to incoordination with reference to the act of comfortable binocular vision. If such tests show 2△ exophoria, we know that, under normal conditions of binocular single vision, there must be supplied innervation to the internal recti to overcome this tendency to divergence. This is the liability upon the positive fusion centers. If, in turn, we should find 2△ right hyperphoria, we should know that the burden to maintain binocular single vision fell upon the centers operating the inferior and superior recti. If, again, we should find 2△ esophoria we should be informed of the fact that, when binocular single vision takes place, neuricity must be delivered through or by the operation of the negative fusion centers acting along the abducens muscles. These tests simply disclose liabilities or inherent tendencies. These inherent tendencies may be check-mated and these liabilities upon the mechanism and centers controlling binocular single vision must be met before binocular single vision can occur. These dissociation tests, therefore, simply disclose inherent errors but they are not in and of themselves sufficient to determine whether or not assistance should be afforded through the giving of muscular exercises or the prescribing of prisms. When we have determined the liabilities we have found but a portion of the data necessary to a logical solution of the problem.

The Binocular Reserves.

The so-called *duction* test measures the *binocular reserves.* These ductions are commonly referred to as adduction, abduction, superduction, infraduction and cycloductions and measure the reserve forces available in the interests of binocular single vision through the media of the internal, external, superior and inferior recti and the obliques (cyclophores) respectively. These ductions — or as we prefer to call them, reserve fusional powers — are obtained for any specific point of fixation through the use of prisms, properly placed, in the case of the four straight muscles and by cylinders in the case of the oblique muscles. It is to be noted that these reserves are of significance and of moment only in the consideration of problems of binocular vision for fixation at the point for which measurements are made. If, for example, fixation is at 20 feet and the various ductions or fusional reserve powers are obtained, the data thus obtained are of value only in the consideration of problems of binocular vision with fixation at 20 feet. They are of no significance, per se, in problems involving binocular single vision at 13 inches, for example. These fusional reserves may, however, be obtained at any point of fixation desired, and the method of test is exactly the same as obtains at 20 feet.

We have, therefore, laid down the two fundamental tests which must be made in order to determine the necessity for muscular exercise or the prescribing of prisms, to wit: (1) The determination of the *liability* or the tendencies to imbalance or actual imbalances which must be overcome before binocular single vision can exist. (2) If this liability is paid, binocular single vision ensues. (3) The reserves must then be found in order that due account may be taken of the imbalances in the light of the reserves. For no function can be taxed with comfort or efficiency beyond a reasonable portion of its total available resources. In the case of accommodation, we generally state that not more than one-third to one-half of the total available accommodation can be used with comfort. In the case of the extrinsic muscles we should say that not more than one-half of the total amplitude or available resources should be demanded if comfort and efficiency are to exist. The error, therefore, or the latent tendency or the liability to diplopia constitute but one feature of an examination; for the reserves, when added to the amount of errors, which must be overcome in binocular single vision, make up the total or maximum available resources.

Vertical Imbalances.

In our discussion, therefore, let us take the vertical imbalances for our first consideration. These are most important, for the reason that small liabilities, or deviations from orthophoria, are of significance inasmuch as the fusion reserves avail-

able for the maintenance of binocular single vision are of low amounts in the case of both the inferior and superior recti sources of innervation. And there is also the further reason that, except in rare cases, there is no other possible source of assistance in the correction of vertical imbalances other than the inferior and superior recti. There is, in other words, no assistance to be derived from the convergence which may accompany the act of accommodation unless the internal recti muscles are mal-attached. It is possible, in rare cases, that the vertical imbalances which may be found are due to over-active interni which are mal-attached. If such is the case, this vertical imbalance will not be found when the excess stimulation to the interni is removed.

As a general rule, the writer believes that a genuine hyperphoria or hypophoria of 1△ or more should be carefully investigated and prismatic assistance given. A sample set of data will illustrate this point. With or without correction, let us assume that 1.5△ of right hyperphoria is discovered. The *liability* is, then, 1.5△ and if binocular vision is enjoyed, the imbalances must be counteracted through the action of the fusion centers controlling the right inferior rectus or the left superior rectus. The reserves should then be determined through the monocular duction test with fixation at 20 feet. Let us say that the findings are as follows: O. D. superduction 4△, infraduction 2△; O. S. superduction 2△, infraduction 4△. If, then, the superduction were to be reduced by 1△ and the infraduction increased by 1△, we should have the two ductions as 3△ in each case for the right eye and *vice versa* in the matter of the increase and decrease for the left. With such findings as these, we also have further evidence of a genuine vertical imbalance. The superduction in the right eye is 1△ greater than the normal amount by reason of the 1△ of right hyperphoria and the infraduction apparent in the right eye 1△ less by reason of the same error. The genuine right superduction and infraduction are therefore 3△. The error to be overcome is 1△ and its correction falls upon the inferior rectus fusion center. The total available is 3△, with a *reserve* of 2△. This error is likely to cause discomfort and occasion a slight haziness or tendency to a wavering fixation. From our line of reasoning it would seem to follow that 1△, base down O. D., or 1△, base up O. S., or else a division of correction between the two eyes would be demanded. A better procedure, however, in many respects is to allow each eye, in turn, to fix and then to add before its mate small quantities of prismatic power, base up or down as the case may be, until the infraduction and superduction are, as determined by test, found to be practically equal. This will afford an experimental method of determining the amount of prism which should be given. For example, in a case showing 2△ right hyperphoria, with O. D. superduction 5△ and

infraduction 2△, and O. S. superduction 3△ and infraduction 5△, it is quite evident that prismatic assistance should be given. The question is, How much? Many would answer: "One-half of the error" or 1△; others would say: "Let us give about ½△" and still others might believe that the full amount should be prescribed. But the requisite amount can be determined by the procedure outlined above.

Tests for vertical imbalances should also be made at the customary reading or working distance, irrespective of whether or not any such tendencies have been found with distant fixation. We have often found little if any vertical imbalances with fixation at 20 feet and yet have found 1△ to 2△ at the reading point. Just recently we had a case in which the distant error was 1△ left hyperphoria and the near error 3△ left hyperphoria. Several points should be emphasized: (1) The possibility of incorrect findings with distance fixation, (2) possibilities of paresis of one or more of the vertical recti and (3) the possible aggravation of the vertical imbalance through a mal-performed act of convergence. Let us make the statement at this point that the superduction and infraduction may be taken at the reading point just as well as at such a fixation distance as 20 feet and just as available information obtained and assistance rendered. The writer employs a Maddox double prism quite commonly for both distant and near tests as to the amount of imbalance, for the reason that the findings on lack of orthophoria vertically can be found at any point desired very quickly and one can be taken immediately after the other with no change of apparatus.

Here are a few cases illustrative of these points:

Case A. ½△ apparent right hyperphoria. Vertical ductions: O. D. superduction 2△, infraduction 3△: O. S. the same. Results the same at 13 inches. Conclusion. No prismatic correction needed.

Case B. ½ to 1△ apparent right hyperphoria. Ductions: O. D. superduction 3△, infraduction, 2△: O. S. superduction 2△, infraduction 3△. At 13 inches 1.5△ apparent right hyperphoria: ductions practically the same as at 20 feet fixation. Prism necessary to cause superduction and infraduction to be equal, each eye fixing and each eye being tested in turn, amounts to 1△. We should, therefore, in this case prescribe O. D. ½△ base down and O. S. ½△ base up in the final prescription.

Case C. The same data for fixation at 20 feet as given in Case B. But at the reading distance the right hyperphoria amounts to 2△. At 13 inches, the right eye ductions are: superduction 4△, infraduction 1△; left eye ductions are: superduction 2△, infraduction 2-3△. Further tests disclose evidences of paresis of the right inferior rectus. We should prescribe a different amount in the prismatic power in the reading as compared with the distance correction, and should give the increased

prismatic power incorporated with the right eye reading correction only. This case is treated by us wholly from the optical standpoint; other tests and treatments by others engaged in caring for human ailments might well be called for and instituted.

Lateral Imbalance Tests Both With and Without Lenticular Corrections.

We believe that tests upon lateral imbalance tendencies should be made both with and without corrections. The notion quite commonly prevails amongst practitioners that hyperopic corrections should be reduced if small amounts of exophoria are found or again that myopic corrections may, with propriety, be carried out to the full if such conditions exist. The reason for this belief is that the exophoric tendency will be reduced and better coordination of the functions of accommodation and convergence obtained if the accommodation is allowed to remain slightly active. For example, in a case of a condition demanding O. U. + 2.50 D. S. and evidencing 3△ exophoria, some practitioners would reduce the lenticular corrections to about O. U. + 1.75 D. S. for the reason, as they give it, that such a reduction will permit of a partial correction of the exophoria through the convergence accompanying the extra accommodation demanded. Others, in turn, would prescribe about 1△ base in, and others would give the full findings, prescribe no prisms and proceed to exercise the internal recti. And yet all of these opinions may be wrong and the case may need simply O. U. + 2.50 D. S. The basis for the determination of the proper procedure will be attempted in the disclosures which follow.

At this point, however, we wish to call attention to the fact that the influence of the correcting lenses upon this matter of binocular coordination, at least in so far as it makes itself evident at the time of the tests, may be determined by the simple procedure of finding the lateral imbalance both with and without the lenticular corrections which have been determined upon as being satisfactory from all other standpoints. For, if with O. U. + 2.50 D. S. there are 3△ exophoria and without any lenses there are still 3△ exophoria, then we feel that we have ample reason for saying that the exophoria has no inherent connection with the accommodative function, and hence there is no reason for expecting a reduction of the exophoria by reason of any changes in lenticular corrections. If, however, with correcting lenses there should be 3△ exophoria and without these lenses 1△ esophoria, then there is evidence of a direct effect of the correcting lenses upon the lateral imbalances. As to whether these lenticular corrections shall be reduced, prisms incorporated, and so forth, is a matter to be discussed in other paragraphs.

Exophoria with Fixation at Distance.

The *liabilities* are found by some suitable test such as the Maddox rod, Maddox double prisms or other dissociation device such as the employment of a 6△ to 8△ prism, base up or down, before one eye. The essential point is that complete dissociation be accomplished in order that the element of *fusion*, which is the function tested in the *duction* measurements, shall be eliminated. We have in a preceding paragraph stated that such lateral imbalance tests should be made both with and without correcting lenses. Let us return to our previous citation of a case needing O. U. + 2.50 D. S. and exhibiting 3△ exophoria, both with and without such lenses. Shall prisms be incorporated? The answer must depend upon the *reserves* as demonstrated by the duction tests. If the adduction is 8△, then we have evidence that the total amplitude of convergence available at 20 feet is 11△, *i. e.*, the sum of the error and the amount of the reserve. We have a liability of 3△ which is paid and a reserve of 8△. In spite of the general run of teachings to the contrary — on the basis that a normal or strong adduction at 20 feet should be 15-20△ and if not should be built to this point — we maintain that no prisms are called for, since the total error or *liability* is but 3/11 or 30 percent of the total available resources, while the reserves are 8/11 or practically 70 per cent. We believe that this error of 3△ exophoria can be overcome with comfort in general if the *amount of the error does not exceed one-third to one-half of the available resources*. This statement we believe to be a safe criterion. If, however, the error should be 6△ exophoria and the reserve should be 6△ or less, then we have ample evidence of the need of corrective treatment. But before this corrective treatment is administered, or at least simultaneously with it, various other tests and examinations should be made. Possible sources which may cause a low adductive reserve are: focal infection due to teeth, tonsils, sinuses; paresis of centers due to lues and so forth; pluggage at the root of the nose; general nervous debility; auto-intoxication. There are also factors which may be of importance from the etiological standpoint. In the case cited, however, we have evidence of a total positive fusion amplitude of 12△ with fixation at 20 feet. This is not, per se, a weak fusion amplitude, but we are certain of the fact that the *liability upon the positive fusion centers is too great in the light of the fusion reserves*. We should, therefore, in such a case as this prescribe the lens corrections demanded and in combination with these add O. U. 1△, base in. This relieves the liabilities upon the positive fusion center to the extent of 2△ and assists nature to that extent. We should also recommend prismatic and various ocular gymnastic exercises in the hope of building up a larger reserve. Such a case as this should be re-examined at stated periods.

Various opinions exist as to the use of prisms correcting lateral imbalances. Some claim that they are ultimately of no account, since a weakness is simply sustained by prisms and conditions soon return,to their previous state or even demand further prismatic assistance. The writer's experience is not in conformity with this view, although he is free to admit that the prismatic elements have to be increased in quite a number of cases. As often, however, after sufficient exercising and with proper hygienic conditions obtaining, these prisms may be removed or reduced. That the prisms may have to be increased in power is no argument against their use, any more than the giving of O. U.+ 1.00 D. S. to a young hyperope is to be condemned because of the fact that in a few years he may need O. U. + 2.00 D. S. Certainly his ocular weakness and need of assistance will have increased. The writer does feel that, all other data and facts being considered, vertical imbalances are of much greater significance than are the usual run of lateral imbalances found in the course of a daily office practice. But when lateral prisms are needed and when ocular efficiency and general nervous tone are increased and when uncomfortable eyes are made comfortable, they should be prescribed. But it is nonsense, as we see it, to arbitrarily give a 1Δ, base in, in a case exhibiting 3Δ exophoria. For if the point of the argument thus far has been grasped, it must be apparent that a condition of 3Δ exophoria is, in and of itself, of no significance unless considered with reference and regard to the fusion reserves. This basis we feel will enable any intelligent practitioner to prescribe, in the relatively few cases really needing them, the proper prismatic corrections.

In cases of exotropia, on the other hand, we may well call attention to the fact that marked improvement in and the preservation of the function of binocular single vision are often gained through the prescribing of prisms in conjunction with prismatic exercises. Many such cases can be materially assisted, but progress is slow and discouragement easy, with consequent neglect and failure. Two fundamental points need attention in such cases: (1) As a general rule the acuity of one eye is much lower than that of its mate and quite commonly the refractive error is greater in the deviating eye. If the exotropia is alternately but little may be hoped for or expected, since the acuities of the two eyes are generally about the same. The first procedure is, therefore, by bandaging, covering or heavily fogging the better eye, to endeavor to develop the vision in the poorer seeing eye. (2) By the use of prisms placed before the deviating eye it is often possible to stimulate binocular vision. When the requisite amount for binocular single vision has been found, the prism power may be slowly reduced. This in itself exercises the externi and draws nerve energy from the proper centers. Step

by step this may be improved and possibly a very decided improvement be obtained.

It is an open question as to how much should be attempted in these cases of exotropia if the subject is ten years old or past. But in the case of children from early infancy up to seven or eight years of age there seems to be no reason to doubt the wisdom of attempting to develop and maintain the sense of fusion as enjoyed in the act of binocular vision. In the case of young children we should say that the great underlying principles were: (1) Development of acuity and the giving of carefully determined refractive corrections and (2) the giving of the least amount of prism which will enable the act of binocular vision to obtain. Slow reduction in prismatic corrections is then to be indulged in, until such time as no further coordination seems probable. In such cases, also, prismatic and gymnastic exercises are to be strongly recommended.

Esophoria with Fixation at Distance

In the first place, it should be noted that 20 feet fixation is not infinity. Hence, when a pair of eyes fixes a small point of light at 20 feet, there is both a small amount of accommodation and of convergence involved. The accommodative change amounts to about 1/6 diopter and calculations show that for a pupillary distance of 60 mm. an amount of convergence equal to practically 1△ is demanded. Therefore, if orthophoria actually exists for very long distances of fixation and if fusion is completely allayed in tests at 20 feet, there should be evidenced an esophoria of about 1△. The import of this remark is, of course, also applicable to exophoric tendencies discovered at 20 feet. For example, 3△ exophoria are actually 4△ exophoria, since the sum of the apparent 3 plus the inherent overconvergence of 1△ associated with fixation at 20 feet is the measure of the true disclosable imbalance.

As a result, therefore, of the considerations of the foregoing paragraph it is evident that a condition of 1△ esophoria is to be considered as indicating orthophoria in tests with 20 foot distances. Lenticular findings should not be in anywise modified by reason of such a finding.

As a general rule, and unless there is distinct proof to the contrary, esophoric tendencies are indicative of over-accommodative innervation. If we should find a hyperopia of O. U. + 1 D. S. and should find 3△ esophoria when such correcting lenses are worn, we should suspect that our case was in reality undercorrected and that greater convex lens power should be attempted even though a slight temporary blur or fog of distant letters existed. In such cases it is always wise to attempt the addition of small amounts of plus lenticular power as a binocular procedure.

Quite frequently O. U. + 0.25 D. S. to O. U. + 0.75 D. S. can be added without serious impairment of visual acuity.

And again, the actual influence of correcting lenses upon the esophoric conditions can be determined through tests made upon the extrinsic muscular imbalances both with and without these correcting lenses. It will be a matter of much interest and instruction to any practitioner to determine, in a few cases evidencing some degrees of esophoria, the influence of increasing spherical power upon the esophoria. We believe from the results of our own observation that, except in rather rare cases, esophoria is always a clear indication of accommodative or ciliary strain or over-stimulation and excessive innervation. The remedy for this condition of affairs obviously lies in proper refractive corrections and not in the prescribing of prisms. These proper refractive corrections may involve two pairs of glasses (equivalent in one sense of the word to bi-focals), one giving the best acuity deemed advisable for general wear and another correction for reading and close working purposes involving some (say half-diopter or thereabouts) additional convex lens power.

Obviously prisms are, as a general rule, absolutely uncalled for in the bulk of cases showing a few degrees (one to three or four degrees) of esophoria. This statement is made for the reason that esophoria is evidence of an excessive convergence, which means that too much convergence is the natural tendency and the eyes, in order to enjoy binocular single vision, must be coordinated through a quantity of neuricity delivered from the negative fusion centers along the channels of the external recti in order to compensate for the excessive action. This means a creation of energy which must in turn be killed or annihilated in so far as its results are concerned. The use of prisms, base out, would simply mean that the excessive energy involved in the overconvergence would be allowed to continue, but that the compensating nerve force from the negative fusion centers would not be called into action, for the prisms would optically deviate the paths of the light rays, instead of the foveae being swung into the line of the undeviated rays as would necessarily be the case if the prisms were absent.

Prisms, base out, in esophoria of several degrees may be permissible if proof indicates that the muscular imbalance is due to anatomical rather than innervational causes. Also, such prisms may be permissible if, after full and proper refractive corrections are worn for some time, these esophoric tendencies continue and if by proper tests it is found that the negative fusion reserves are not greater than the quantity of esophoria or esophoric liability. For example, let us say that O. U. + 1.00 D. S. is the apparently satisfactory refractive correction. Both with and without correcting lenses there is an esophoria of 4△. Months of time spent in wearing these glasses shows no improve-

ment in the esophoric tendencies and complaints of discomfort still persist. Tests disclose that the esophoria is 4△ and that the reserve negative fusion, or abduction, is 4△. This means that the total negative amplitude is 8△, of which one-half is constantly in demand in the act of binocular single vision. In such a case as this it is doubtless good practice to prescribe about O. U. 0.75△ base out. This will mean a relief to the negative fusion centers of 1.5△, or in other words it means that we may consider the demand in overcoming the esophoric tendency as being reduced to 2.5△ or may consider the giving of the 1.5△, base out, as an increase of that amount in the negative fusion.

Hyperphoria, Exophoria and Esophoria with Fixation at the Reading Distance.

The same fundamental principles of finding the liabilities and reserves, hence total resources, are applicable to any point of fixation. They are therefore applicable to the determination of the possible need of prismatic assistance or prismatic and gymnastic exercises at the subject's normal reading or close working point. The same experimental methods and the same logic hold throughout.

At points of fixation within infinity (or practically 20 feet) accommodation is needed to give distinct vision and convergence is needed to give singleness of vision. The act of accommodation may have accompanying it the full complement of convergence needed to give binocular single vision by virtue of the fact that the whole of the convergence may be what we may call *central* or what some of us designate as *accommodative* in contradistinction to *fusional*. And yet in another case there may be no accommodative convergence, which means that when the eyes look at a nearpoint and see distinctly they do not enjoy *central* binocular vision. In this case, then, the act of binocular singleness of vision must be accomplished through the *fusion* centers. In still other cases, and by far the large majority, we find that about two-thirds of the convergence innervation and act is central and the remaining one-third is fusional. Obviously the fusional demand is the liability at the reading point fixation, since any central or accommodative convergence is the accompaniment of the accommodative act. We can therefore speak of the lack of central coordination in the act of binocular vision as *accommodative exophoria*. If perchance there is an excess of the accommodative or central innervation needed for coordination, we could very properly speak of this as *accommodative esophoria*. Therefore, it seems to us to follow as a matter of clean and simple logic that the matter of the prescribing of prisms in reading corrections should be based upon the same two fundamental tests as we have

advocated for distance fixation, namely: (1) fusional liabilities and (2) fusional reserves. The fusional liabilities are determined at close points of fixation in the same or analogous manners to those employed at 20 feet, such as the Maddox rod and small light sources, Maddox double prism and a dot on a card or an 8△ base up (or down) before one eye and some small fixation object. The fusional reserves can be found by getting the adduction and abduction at close points of fixation by the use of a vertical ruled line or a row of vertically placed letters. These tests involve the use of prisms, base out — for the positive fusion reserve or adduction, and prisms, base in — for the negative reserve fusion or abduction.

It may be worth the space taken to make the comment that adduction is purely positive fusion reserve and abduction is negative fusion reserve. The data obtainable are applicable to the conditions existing at the point of fixation only, whatever that may be. This point of fixation may be anything desired up to the limit of ability to get and maintain binocular single vision. We believe that tests upon the fusional liabilities — exophoria, esophoria, hyperphoria and hypophoria — and upon the fusional reserves — adduction, abduction, infraduction and superduction — should be made at two points, namely: (1) 20 feet or at a distance involving not less than 10 feet, and, preferably to either, something like 40 feet and (2) the subject's ordinary working or reading distance. For it does not follow that, should muscular conditions be found satisfactory with distant fixation, the same will continue throughout and exist at near fixation points and *vice versa*. For the conditions to be met are entirely different in close and distant fixation points.

With the hope that a tabulation of the underlying principles of these discussions may be made clearer and admit of comparative study, we are adding the appended tables.

FIXATION — 20 FEET. (Distance).

Extrinsic Muscular Condition	*Source Paying the Liability*	*Reserve Involved*	*Amount of Liabilities*	*Amount of Reserve*	*Prisms Indicated*	*Other Treatment Needed*
Exophoria	Accommodation or Fusion	Positive fusion	2△ 4 6 6	10△ 10 10 6	No No Possibly Yes	No No Exercise (?) Thorough physical examination
Esophoria	Fusion	Negative fusion	1△ 3 3 3	7△ 7 5 3	No No Possibly Yes	No Full corrections " " " "
Hyperphoria	Fusion	Sub-fusion	½△ 1½ 2	3△ 3 1½	No Yes Yes	No Exercise (?) Exercise
Hypophoria	Fusion	Super-fusion	½△ 1½ 2	3△ 3 1½	No Yes Yes	No Exercise (?) Exercise

FIXATION — 1 FOOT. (Reading)

Extrinsic Muscular Conditions	*Source Paying the Liability*	*Reserve Involved*	*Amount of Liability*	*Amount of Reserve*	*Prisms Indicated*	*Other Treatment Needed*
Exophoria (accommodative)	Fusion	Positive fusion	7△	18△	No	No
			13	18	No	No
			18	18	Probably	No
			20	14	Yes	Possibly
Esophoria (accommodative)	Fusion	Negative fusion	2△	12△	No	Full correction
			4	10	No	Extra reading correction
			6	6	Possibly	Possibly
			6	4	Yes	Possibly
Hyperphoria	Fusion	Sub-fusion	½△	3△	No	No
			1½	3	Yes	Exercise (?)
			2	1½	Yes	Exercise
Hypophoria	Fusion	Super-fusion	½△	3△	No	No
			1½	3	Yes	Exercise (?)
			2	1½	Yes	Exercise

Conclusion.

We believe that the prescribing of prisms should be based wholly upon these criteria: (1) The liabilities, (2) the reserves, and (3) the hypothesis that no function can be taxed to an amount greater than one-third to one-half of its total available resources.

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ASTIGMATISM

by

HOWARD D. MINCHIN, Ph. D.

Professor of Applied Optics

The Ohio State University, Columbus, Ohio.

ASTIGMATISM

In a study of the refraction of the eye we consider first a perfect eye. This is one in which the refractive surfaces are considered to be surfaces of revolution having the part of each concerned in refraction spherical or approximately spherical. These surfaces form an optically centered system. The different surfaces are produced by the rotation of an ellipse or circle about the optic axis. For all practical purposes they are generated by circles of revolution. Such surfaces have the same curvature in every meridian. Light passing through such a series of surfaces will be equally refracted in each of the several meridians. Rays emanating from a point object will converge and form a point image. The exception to this condition being only when a large aperture is used. When this is the case spherical aberration results.

In the case of the eye the amount of spherical aberration is negligible.

The surfaces of the perfect eye approach more nearly an ellipsoid of revolution with two axis — a major axis — the optic axis and the axis of rotation; the other axis is perpendicular to this one and equal in length in every direction.

In practice it is found that very few eyes come up to this standard. The curvature of the cornea is nearly always greater in some one meridian than in the one perpendicular to this.

Such an eye has three axes and those are of unequal length. It may be called an ellipsoid with three unequal axes — the optic axis, the axis of the vertical meridian, and the axis of the horizontal. The axis of the vertical meridian being usually shorter than that of the horizontal.

This difference in meridians leads to a defect in the image formed by the eye. The rays of light are focussed differently in the different planes and therefore a point object does not produce a point image. The image will vary according to conditions. It may be a line, a circle, or an ellipse. The phenomenon is called *Astigmatism*. This means without a point.

The difference is often very small and is then negligible. When it is large enough to impair vision it calls for correction.

Cause of Astigmatism

It has been determined that the cause of astigmatism lies in irregularities of curvature in the different surfaces of the eye or to eccentricities of these surfaces.

The cornea is the common seat of astigmatism and it is because of irregularities of curvature. The cornea is not as a rule an ellipsoid of revolution but it is rather an ellipsoid with three unequal axes — the optic axis, the axis of the vertical meridian, and the axis of the horizontal.

The astigmatism resulting is congenital and usually remains stationary through life. Such astigmatism may be considerable in degree. The highest degree of corneal astigmatism usually results from operations. This form usually becomes modified in degree in the course of time, getting less than it measured just after the operation. It may even become negligible. However, it more often persists in some degree.

Astigmatism may have its seat in the crystaline lens. It may be either passive or active in form.

Passive astigmatism of the crystaline lens occurs when the globe of the eye is flattened in one meridian. This flattening tends to compress the crystaline lens and it approaches the compressed form of the cornea and the static crystaline lens astigmatism adds itself directly to that of the cornea.

In certain cases the principal meridian of the astigmatic crystaline lens does not have the same direction as that of the cornea, in other cases it is parallel with that of the cornea but in such a way that the maximum curvature of the crystaline lens corresponds to the minimum curvature of the cornea, and the least convex meridian of the lens has the same direction as the most convex one of the cornea. In these latter cases the astigmatism of the crystaline lens may partly or wholly annul that of the cornea; or it may even exceed it.

Donders in 1864 stated that with a high degree of asymmetry of the cornea there is also an asymmetry of the crystaline lens which acts in such a direction that the total astigmatism of the eye is nearly always less than that of the cornea. This astigmatism of the crystaline lens he calls active or dynamic. It is due to unequal contraction of the ciliary muscles which causes the lens to become more convex in one direction than in another.

Dobrowlsky brought numerous proofs forward to prove the validity of Donders statement.

A tilting of the lens will also produce astigmatism. This condition obtains when the axis of the lens is not centered with respect to the rest of the refracting surfaces.

Astigmatism due to the crystaline lens is suceptible of change with age and this may result in an increase or in a decrease of the amount of astigmatism of the eye as a whole. This will depend

on whether the astigmatism of the lens acts to increase or to decrease that of the cornea. However, astigmatism is most likely to increase with age.

Astigmatism may be classified as Congenital or as Acquired.

There are various types of astigmatism and these are usually considered under the following heads. Regular and Irregular astigmatism.

Regular astigmatism is classed as (1) Simple Hyperopia astigmatism; (2) Simple Myopic astigmatism; (3) Compound Hyperopic astigmatism; (4) Compound Myopic astigmatism; (5) Mixed astigmatism.

Regular astigmatism is the type due to a regular variation in the curvature of a surface from meridian to meridian. It is generally corneal in its cause.

In regular astigmatism the vertical meridian of the cornea is usually of the greatest curvature. Because of this fact astigmatism of the vertical meridian is said to be with the rule, astigmatism in the horizontal meridian is then against the rule. These two meridians are at right angles to each other and are called the principal meridians. A cornea so affected is in shape quite like an egg.

(Diagrams will be shown here).

Simple Hyperopic Astigmatism is the condition where one meridian of the eye is emmetropic and the meridian at right angles to this is hyperopic. The vertical meridian focusses parallel rays on the retina; the horizontal focusses them back of the retina. The retinal image of a point object will be a line and is usually horizontal. Authorities seem to agree that about 5 to 6 per cent. of human eyes have this form of astigmatism.

Simple Myopic Astigmatism is the condition where one meridian of the eye is emmetropic and the one at right angles to this is myopic. In this case the horizontal meridian focusses parallel rays on the retina and the vertical focusses them in front of the retina. The retinal image of a point is a line and is usually vertical. This type is not of very common occurrence, possible 1 to 1½ per cent. of eyes are so affected.

Compound Hyperopic Astigmatism is the condition where there exists a combination of axial ametropia and simple hyperopic astigmatism (curvature ametropia). Both meridians have their focus back of the retina, one being farther back than the other, usually the focus of the horizontal meridian is the farther back. The retinal image of a point is never a line but is more of an oval.

Compound Myopic Astigmatism is a combination of axial ametropia and simple myopic astigmatism. In this case both meridians have their focus in front of the retina. One being farther in front than the other. Usually the focus of the vertical meridian is the farther forward. This is claimed to be the

most common form of astigmatism in myopic eyes. About 8 per cent. of myopes are so affected. The retinal image of a point is an oval.

Mixed Astigmatism is a condition of simple myopic astigmatism combined with simple hyperopic astigmatism. One meridian focusses parallel light in front of the retina and the other focusses it back of the retina. About 6 to 7 per cent. of eyes are so affected. The retinal image of a point is an oval or a circle.

Astigmatism is also classed as Symmetric and Asymmetric. Symetric astigmatism is the condition where the combined values in degrees of the astigmatism of the maximum added to the astigmatism of the minimum is equal to 180 degrees. Asymmetric astigmatism is the reverse of symmetric. In this type the combined values in degrees of the cylindrical axes do not equal 180 degrees.

Symmetric astigmatism is generally found in cases of a regular physiognomy. The centre of each pupil being at an equal distance from the median line of the face. Asymmetric astigmatism is found usually with an asymmetric face.

Irregular astigmatism obtains when the refractive power in any single meridian is not everywhere alike. Rays of light passing through this meridian fail to focus at a point. This form of astigmatism may be due to a diseased condition of the cornea. It is usually located in the cornea and is the result of some break or rupture interrupting the curvature.

The one principal meridian may show regular astigmatism and the other may show irregular. Clear images are not produced, they are always hazy.

Some irregular astigmatism is present in every eye.

The crystaline lens is made up of several layers or sectors reaching from the equator to the centre. Each layer differs in curvature and in refractive power from every other layer. It follows that rays from a point object at a great distance are refracted unequally by the different layers. When this difference is slight the different images overlap and we get the impression of a star rather than of a point.

When the difference is not negligible one or more points of the apparent star become more distinct than the others and monocular diplopia develops.

Irregular astigmatism reduces the vision and causes distortion of objects which may not be corrected by the use of lenses.

Sometimes vision is improved by the use of a pin hole disc. This reduces the illumination and also shuts out the peripheral rays thus lessening the irregular refraction and reducing confusion.

Irregular astigmatism located in the cornea may be due to scars, or lenticular opacities and these are readily detected by the use of the ophthalmoscope.

Irregular astigmatism may be detected by the use of the plane mirror retinoscope and shows up as wavy lines against the red background and the reflex will appear in several portions some moving with the mirror and some against.

The Determination of Regular Astigmatism

The presence of astigmatism is usually revealed in the tests for visual acuity. Errors made in the test by the patient will reveal the trouble. He will mistake certain letters that are somewhat similar. O will be mistaken for Z or it may resemble H. The first when the vertical meridian is not affected; the second when the horizontal is not.

Another evidence is that a change of spherical lenses generally exerts less influence than in the case of a non-astigmatic eye.

We proceed to determine astigmatism by excluding one eye and first finding the spherical lens that will give the greatest visual acuity. We choose the weakest negative lens or the strongest positive one that gives best acuity. We next use a cylindrical lens to correct the incorrect meridian.

There are cases where a spasm of accommodation has existed during the examination and when the astigmatism is corrected this spasm relaxes with the result that the patient sees as well, if not better, with a weaker negative lens or with a stronger positive one. This does not nullify the examination. The astigmatism found is present but a weaker negative or a stronger positive lens is furnished.

In such a case it is well to check results by different methods. It is probably best to repeat the examination on a later day before prescribing the correction.

When one eye is tested it is to be excluded and the other one tested.

Subjective Tests

Absence of normal acuteness of vision is one of the first evidences of astigmatism. If this condition has existed with equal degree from birth it is more than likely due to astigmatism. After determining the degree of imperfection of acuteness of vision we find the principal meridians. Then examine the image produced by use of the stenopaic slit. Determine the state of refraction of each of the principal meridians.

What we need to know of astigmatism of the eye under examination is:

1. It existence
2. Direction of the principle meridians
3. Refractive conditions of meridians
4. The degree of astigmatism

Objective Signs of Astigmatism

These are inferior to the subjective signs and can not be relied upon to show with accuracy the existing asymmetry. The value lies in the connection they have with the cause. This statement is from Donders. I believe with our improved instruments the statement is much less true than it was when he wrote it. The ophthalmoscope supplies us with a series of objective signs that are reasonably dependable.

Astigmatism occurs mostly in hyperopes. If diminished acuteness of vision obtains, in such persons Asymmetry is generally the cause.

The cornea usually shows more decisive signs and it may be readily studied by the ophthalmometer.

With the ophthalmoscope asymmetry may be discovered by the fact that the vessels proceeding in different directions from the optic disk do not show up equally.

Back in 1861 Dr. Knapp at a meeting in Heidelberg called attention to the difference in shape of the optic disk in cases of asymmetry.

The objective determinations of astigmatism are best made by use of the ophthalmoscope.

With the refractive power differing in two meridians of the eye the retinal image is not uniformly clear. The observer will not be able to see distinctly all parts of the image at once.

Horizontal lines are seen distinctly when the vertical meridian is adapted and vertical lines distinctly when the horizontal meridian is adapted.

The enlargement of the image will be different in the different meridians.

If we use the erect image the fundus in the meridian of least power is seen by means of a weaker positive lens than in the meridian at right angles to it. Enlargement is less in the meridian of least power.

If we use the inverted image these conditions will be reversed. The papilla will appear in the inverted image elongated horizontally.

The size of the inverted image of an astigmatic eye varies unequally in the different meridians.

The presence of astigmatism is shown in pupilloscopy by the fact that the illumination is not the same in all meridians. The pupillary lustre moves as the mirror moves.

In making ophthalmoscopic determinations of the degree of astigmatism we find the spherical lens that will correct each meridian. We find the strongest positive lens that will correct the vertical, this is when the horizontal line is best seen. We then find the strongest positive lens that will correct the horizontal. The difference between these two will give the astigmatism.

Suppose we find for the vertical correction a plus 2 and the horizontal plus 5. The astigmatism is 5 - 2 equals 3 D.

We should then check by the subjective method.

We may detect astigmatism objectively by means of the image formed on the fundus. For this use a ring with cross wires.

(Demonstrations to be shown here.)

If the eye reflects light normally all radii of the star image formed upon the retina will appear equally distinct at the fundus. If the eye possesses any astigmatism some of the radii will be more distinct than others. The meridian that is best adapted to the rays reflected by the ophthalmoscope is parallel with the most diffuse line. The degree of astigmatism is measured by that cylinder that placed before the eye equalizes the clearness of all lines. The position of the cylinder indicates the direction of the meridian. In case a spherical lens is needed to give most distinct vision the total correction of the ametropia will be the combination of the sphere and the cylinder.

(Demonstrations here).

Targets To Be Used In Testing Astigmatism

1. The wheel or clock arrangement of lines.
2. Groups of lines, say, four in a group and arranged each group in a different direction. Have the patient name the group he sees the most clearly and the group he sees the most diffuse.
3. Use a series of concentric circles. In the meridian not adapted to the distance of this target it will have much the appearance of an hour glass.
4. Use letters built up by the use of parallel lines. In the construction of the letter these lines will have different inclinations in the letters as a whole. The letter seen clearest will give the meridian of adaptation.
5. Two luminous points so arranged that the one revolves around the other. To the normal eye these openings appear as two points. To the astigmatic eye they appear as two lines. When they are so placed that each line is a prolongation of the other they indicate the direction of one principal meridian. The other is perpendicular to this.
6. A weak cylinder has been used by some. This cylinder is rotated in front of the eye which has been corrected for its greatest visual acuity by the application of a spherical lens. The position of the cylinder that gives equal clearness to all parts of the field gives the position of the meridians. By tests the degree of the astigmatism is found. This is accomplished by changing the cylinder until the one is found that gives the best conditions of vision.

One advocate of the test uses a convex or a concave cylinder of about 1D. This cylinder diminishes the vision of the normal

eye, or of one made normal by a correcting lens, in whatever direction it is placed in front of the eye. In an astigmatic eye the effect is not the same in all meridians.

(Demonstrations).

Method Of Procedure

7. The astigmatism may be determined by the use of spherical lenses alone. This is accomplished by finding the degree of astigmatism first in one meridian and then in the other. Having found the principal meridians a slit is placed before the eye in the direction of one of the meridians. The refractive power is determined for this meridian by the use of spherical lenses. Then the slit is placed in the other principal meridian and its refractive power is determined. From the data thus obtained we find the astigmatism.

Suppose the first meridian tested shows hyperopia of 3D and the other one shows hyperopia of 2D. The astigmatism is therefore 1D. The prescription will be a plus 2 sphere combined with a plus 1D cylinder. The cylinder to be placed in position depending on data found.

8. The astigmatism may be found without the use of the slit.

Find the weakest negative lens or the strongest positive lens that will give the lines in some one direction the clearest. Then find the lens that will give the lines perpendicular to these the same clearness — that is, that corrects the other meridian. Suppose we find a positive sphere of 2D for the vertical lines, and a negative sphere of 3D for the horizontal lines. This eye is then hyperopic 2D in the horizontal and myopic 3D in the vertical. Its astigmatism is 5D. The correction may be as follows: A plus 2D cylinder axis vertical combined with a minus 3D cylinder axis horizontal.

This method has been found to give very good results. It is well however, to check with the correction before the eye.

One weakness of the method is the fact that the eye may make different accommodative efforts in the two examinations.

Other Methods: Many other methods may be suggested and others may yet be determined as investigation is carried on.

Recognition of Astigmatism

1. Astigmatism may be studied by noting the change in form of the papilla in the direct and indirect method. It will appear more elongated in the direct method.

2. In pupilloscopy the astigmatism is recognized by the fact that the phenomenon of illumination are not the same in the different meridians.

3. Ophthalmoscopic determinations.

4. Astigmatism is recognized objectively by means of the

image formed on the fundus of the examined eye by either the erect or the inverted image.

5. A pencil held in different directions before the eye will give to one somewhat adept very fair data.

6. Stoke's lens and ophthalmoscopic mirror. Two cylinders of equal power, one concave and the other convex are mounted so as to turn one over the other in opposite directions.

7. Observance of the ocular lustre when looked at from some distance.

Editor's Note: Prof. Minchin has only given an outline of his address. The full lecture was not ready when this went to press.

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PRESBYOPIA
and
SUB-NORMAL ACCOMMODATION

By Dr. W. B. Needles

President Northern Illinois College and Needles Institute of Optometry.

The subject which has been assigned to me is of vital importance to every man in Optometry. It affects the daily practice in office, shop and store. Everyone knows that old age brings, as one of its attendant evils, failing vision, but we frequently do not consider the fact seriously. We are greatly concerned over those who have refractive errors of which they are not aware, and we have proposed various educational campaigns to inform such persons of their condition, but we have sometimes lost sight of the fact that every person is destined, if he lives, to become a presbyope and to realize in his own experience a need for glasses in order to see.

Neglected Subject

Presbyopia is the foundation upon which the practice of many optometrists was first laid. In ancient times peddlers and vendors sold spectacles for this use and there has never been a time down to the present when the correction of old sight has not formed an important part of the practice of every refractionist. As we delve into the science of Optometry and its correlated branches we are disposed to leave behind such commonplace subjects as this, considering it of too little importance to merit any extended study. However, we need occasionally to be reminded that presbyopia is often imperfectly understood and that there is need for greater knowledge, not merely of its theory, but practice.

Mistakes Expensive

Certain large optical concerns make a practice of preserving all of the valuable lenses which are thrown back on their hands by dissatisfied patients. These lenses are labeled and filed in what is called the "morgue" in the hope that some day they may be resurrected and put to use. It is perhaps safe to say that the majority of such lenses are bifocals of the "ground in" variety, every one of which is expensive, and when we realize that many "morgues" contain hundreds of pairs of such "misfit" lenses, we must appreciate the fact that ignorance of presbyopia and how to correct it, may be a source of tremendous expense to the optometrist as well as discomfort to the patient.

Any mistake in prescribing for presbyopia is inexcusable. The common opinion that this error is easily corrected, is not far from the truth, provided one really understands it, but for years upon years, it has been customary to measure presbyopia by unscientific methods. Even those who exercise utmost caution and show great skill in their measurement of deformities and malformations of the eye are sometimes careless in these tests.

Accepted Theory of Accommodation

We shall begin our study with a discussion of the mechanism of accommodation, since it is the failure of this function which provides our topic. The anatomy of the eye is well understood and the structures which participate in this act have been so carefully studied under the microscope and otherwise, as to leave no doubt of their character and little uncertainty as to their operation. Of the various explanations of accommodation offered from time to time, the one which has stood out as the most logical and which is almost universally accepted is that offered by Helmholtz.

Let us consider the theory of Helmholtz, which we will present with a few slight modifications: The crystalline lens rests in a depression in the front surface of the vitreous body, known as the lens fossa. The hyaloid membrane which encloses the vitreous humor divides on its front surface into two membranes one of which lines the lens fossa and the other passes over the front of the lens, holding it in place in its cup. These two portions of membrane form the Zonule of Zinn and the one which passes over the front of the lens is known as the suspensory ligament. It is highly elastic and by its tension, draws the lens in repose into a flattened form. The lens is composed of thin, fibrous layers of great elasticity, enclosed within a capsule which is divided by name only, into anterior and posterior portions. In youth it is highly spherical. In fact, if the suspensory ligament be removed from the eye of a child, the lens, of its own elasticity, bulges on its anterior surface almost enough to form a perfect sphere. It is this property which makes accommodation possible. Whenever it attains the slightest freedom from restraint the convexity increases. It is by contraction of the ciliary muscle that the tension of the suspensory ligament is slackened, permitting positive accommodation.

This function operates with greatest efficiency at ten years of age. At that period the ciliary muscle has not nearly attained full strength and yet its contraction is sufficient to produce 14 D. increase in the power of the lens system. This is due to the resiliency of the crystalline lens rather than to the strength of the muscle. At this early age a change begins in the lens which affects its accommodative power. This change is in the nature of a hardening which Fuchs attributes to condensation and loss

of water whereby the layers begin to stiffen. This first forms a nucleus after which all of the superficial layers in time become sclerosed.

Receding Near Point

By the time age twenty is reached the amplitude has diminished from 14 D. to 10 D. and this, notwithstanding the fact that the ciliary muscle has greatly increased strength. Year by year the process of hardening continues until at forty the normal eye has but 4.50 D. of accommodation: about one-third of the amount at age ten, though the ciliary muscle is now fully twice as strong as in childhood. This fact is attested by its size as revealed under the microscope. At age forty the eye is at the threshold of a critical stage. The task of accommodation without artificial aid will soon become too great for comfort. As the lens continues to harden, it will require more and more freedom from the restraint of the suspensory ligament, in order that it may assume the desired convexity. This necessitates an increasing effort of the ciliary muscle, even for a moderate accommodation. In fact, the contraction of the muscle necessary to produce 1 D. of accommodation at middle age is as great as would be needed for twice this amount in youth and there is a rapidly increasing ratio after forty, between the muscular effort required and a given amount of accommodation. At this stage eye pains may become frequent.

Two Causes of Pain

There are two causes either of which may produce accommodative asthenopia. One is excessive use of the ciliary muscle, the other, inharmonious accommodation with respect to convergence. The quantity of this function which constitutes overuse, resulting in fatigue and eye pain, cannot be reckoned in terms of dioptries, partly for the reason that different individuals are affected differently by a given exertion and also because of the variable amount of muscular effort required for a given accommodation at the different stages of presbyopia. The latter factor is the important one. In youth the eye may accommodate for fine print held at eight inches, necessitating 5 D. of added power in the lens and it can sustain this for long periods without discomfort because such action is accomplished at this age with comparatively slight contraction of the ciliary muscle, but in advanced stages of presbyopia change in the lens is impossible except when it is almost entirely free from restraint of the suspensory ligament, and as this is only accomplished by vigorous contraction of the ciliary muscle, it is obvious that the probability of fatigue is great.

Strong Ciliaries

Those, who by excessive use of accommodation, either for correction of hyperopia or for long-sustained near work, have

developed the ciliary muscle to a point of unusual strength, may endure over accommodation for long periods without the signs of asthenopia commonly observed in such effort. There are reasons, however, why there is grave risk in hyper-development of the ciliary muscle and it is the duty of the optometrist to give warning of the dangers which attend uncorrected hyperopia and other causes of excessive accommodation. The nature of this risk will be treated elsewhere.

Inco-ordination

The question of relationship between accommodation and convergence has an important place in our study and in considering it we come to one of the highly interesting functions of the nervous system. It is a physiologic law that muscular actions which are stimulated by way of reflex nerve paths, can function with far less fatigue than those efforts, the energy for which, must come from the cerebrum. Throughout life we are continually engaged in building nerve paths through which we may involuntarily perform movements. As soon as these paths are well established, energy flows through them freely and the muscles which they control can function without violition. Through ages of time the eyes have been required to accommodate and converge co-ordinately. This act repeated in generation after generation, has established congenital nerve paths through which we may comfortably use the ciliaries and internal recti, so long as they contract simultaneously. Should it become necessary to disassociate these functions or modify their relation because of some ocular anomaly, the action is usually attended with fatigue and so long as the eyes are used in this abnormal manner, they will be more or less liable to discomfort.

Maintaining Harmony

It is common opinion that the ratio of accommodation to convergence changes with the coming of presbyopia. This opinion is based upon the fact that the convergence required for fixation at near points remains the same at all ages, while in presbyopia a portion of the accommodation must be supplied artifically through the medium of convex lenses. This would seem to prove that the eyes are compelled to substitute increasing amounts of adduction for convergence as presbyopia develops. This opinion, however, does not take into account the increased muscular effort which all accommodation requires in presbyopia. It may be stated as reasonable that the harmonious relation between convergence and accommodation, established in youth, is not disturbed when an individual is wearing presbyopic glasses of proper strength. If one desires to read at a distance of thirteen inches and is properly fitted with lenses which allow him to use 1 D. of accommodation there is not the lack of harmony between

confergence and accommodation which might at first appear. The convergence demanded for this distance is 3 meter angles, while the accommodation should be 3 D. In this instance, however, the accommodation which is permitted is but 1 D. Presbyopia will have advanced to a point where assuming the presbyopic lens to have been properly selected, the muscular effort necessary for this 1 D, is practically the same as would in youth have furnished the entire 3 D. Therefore, the nervous impulses for both convergence and accommodation are practically the same as they have always been in this act. Comfortable presbyopic glasses will invariably be those which do not disturb this relation. It is surely true that the ciliary muscle in partial presbyopia can endure as great exertion as in youth and this assumption is all the more reasonable in view of the fact that in presbyopia the muscle is invariably heavier and stronger than in the eye of youth.

Premature Presbyopia

It is a matter of great significance that some individuals lose a large portion of the power of accommodation prematurely. This may result from two causes. It may be due to a partial or total loss of tonicity of the ciliary muscle or it may result from abnormally rapid hardening of the crystalline lens. As to which of these is the true cause in a given case, is a matter of great importance in determining the treatment. If the tonicity is subnormal, the cause may be systemic. It may result from medication, from toxines, from lesion due to secondary infection, or some other pathologic cause. In any case, it is well to investigate the cause of impaired muscle tonus and to attempt by calisthenics to develop the ciliary strength until it is sufficient for average needs. On the other hand, if the lens has hardened prematurely, ocular exercise should not be advised since accommodation cannot be restored except by developing a degree of strength in the ciliary muscle which would undoubtedly be dangerous to the well being of the eye. This danger lies in the fact that increased strength brings with it increased size of the muscle. Abnormal size cannot safely be accommodated in the limited space alloted to this muscle. When, by the reason of hypertrophy, it becomes thick and heavy, it crowds against the drainage canals, squeezing them outward against the sclera and flattening them, thus hindering the discharge of the surplus accumulation of aqueous humor and predisposition to glaucoma. It is not merely by chance that this disease so frequently occurs in persons about fifty years of age who have been hyperopes, have neglected to wear their distance correction and have even postponed the use of reading glasses for one reason or another, until the over-taxed ciliary muscles become so large as to produce the results described. It rests upon the optometrist as a serious responsibility to warn all hyperopes

of the importance of wearing their correction and advising regular changes of their presbyopic glasses as accommodation fails.

When to Correct

A patient who, by test, shows premature presbyopia from hardening of the lens, should wear bifocal glasses, notwithstanding the fact that he will probably never again be able to lay them aside. Whatever handicaps result from this early surrender to bifocals, are more than compensated for by comfort and by the protection afforded against possible eye disease.

Association Test

The test by which we undertake to determine the cause of premature presbyopia may not be infallible but its evidence is strongly supported. This test consists of measuring the muscle balance at the reading distance. It is best made by the use of a double-prism and a row of type small enough to demand careful adjustment of accommodation to be visible. The double prism before one eye causes two rows of this type to appear and if properly adjusted, one row will be straight above the other. The companion eye, when uncovered, sees a third row of type somewhere between the other two. This test will reveal one of three conditions: esophoria, exophoria or so called orthophoria at the near point. To explain the significance of this test we would call attention to the fact that when the eyes are thus disassociated by the double-prism, there is no possible incentive for them to converge, except that provided by the relation of convergence to accommodation. To read the type distinctly the eyes must accommodate. If this accommodation has no effect upon convergence and the eyes are six centimeters apart, the test at one-third meter would reveal 18 P. D. of exophoria. It is usual, however, for convergence to be incited to action by this accommodation even though it serves no useful purpose. The extent to which the eyes converge indicates something of the accommodative effort. If the test reveals esophoria, especially if it be of a rather high amount, we would know that accommodation is making a great effort and that the ciliary muscles are being contracted much more than should be needed for the desired result. This would strongly indicate that the weak amplitude is due to a premature hardening of the crystalline lens, necessitating an extreme contraction of the ciliary muscles in order to permit it sufficient freedom to assume a proper increase of convexity. This is also true, though not to so great an extent, where the test shows orthophoria at the reading distance. The tendency of all muscles is to lag when an opportunity is afforded and if convergence does not lag in this test it is evidence that accommodation is being exerted more than should be necessary for this act.

Physiologic Exophoria

Normal eyes in proper association fix upon one-third meter by using 3 D. of accommodation and 18 P. D. of convergence. It has been found customary for emmetropic eyes, under the muscle test, as described at thirteen inches to permit a lag of the internal recti amounting to about 8 P. D., so that the test will show 8 P. D. of exophoria. This has been considered a proper showing and it is sometimes described as a physiologic exophoria. The true significance of the test is that accommodation is equal to its task, the lens has not hardened prematurely and there should be no need for bifocal glasses.

Measuring Amplitude

The test by which we undertake to determine if accommodation has failed because of loss of muscle tonus, would consist of checking the aforementioned phoria test with the test of the amplitude of accommodation. This is an important part of every examination whatever the age of the subject. Its findings should be carefully recorded, to be reckoned with both during the test and subsequently. Various methods have been proposed for making this test, but the following plan is dependable and serves every useful purpose. Place before the eyes the ametropic correction, if any, hold the test card bearing the finest type at sixteen inches. If it cannot be read distinctly, add plus 2 D. spheres before the ametropic correction, in order to bring the punctum remotum forward twenty inches. The punctum proximum may then be found by requiring the subject to read aloud while the card is moved toward him. When the nearest distance is found at which one entire line can be read, it should be carefully measured. The dioptric value of the P. R. subtracted from that of the P. P. gives the amplitude. In other words, we must subtract the plus 2 D. lenses which we have supplied.

When to Assist

The question of sufficiency of amplitude is based upon the uses to which the eyes are subjected. If they are employed daily in sustained work at a near distance which necessitates a great deal of accommodation, the amplitude may prove insufficient, whereas in other duties it would be entirely sarisfactory. In all cases, a sufficient amplitude would be an amount great enough so that at least half of it can be kept in reserve while doing sustained work. To ascertain this we must determine the distance at which one is required by his occupation, to focus his eyes. As a rule, this distance is about sixteen inches, the dioptric value of which is 2.50 D. We may, therefore, say that an amplitude of 5 D. would be sufficient whatever the age, provided the muscle test shows exophoria at the near point. If the amplitude drops

below this amount we would prescribe bifocal glasses unless the subject is younger than he should be according to Landolt's table of amplitudes and even in these cases, we would give bifocal glasses if the muscle test indicates esophoria at the near point.

In determining the bifocals to be used, our rule is to subtract one-half of the amplitude from 2.50; the remainder is the add.: Thus, one whose amplitude is 3 D. would require a bifocal add. of plus 1 D. If the amplitude is 1 D. the add. should be plus 2 D. If the amplitude is entirely gone the add. would be plus 2.50 D.; this being the strongest ever used. We must remember that bifocals are service glasses. They are distance glasses with an attachment making it possible to see near objects distinctly. If the far point of the added portion is brought closer than sixteen inches, their usefulness is greatly impaired. Any person who has lost all accommodation and has such poor acuity that he cannot read comfortably with plus 2.50 D. add. should be furnished an extra pair of stronger glasses for the sustained near work. He should also have bifocals with plus 2.50 D. add. for eating, writing and the ordinary uses of constant wear.

Ciliary Exercise

When it has been decided that a case of subnormal accommodation is due to impaired tonicity of the ciliary muscle, it would of course be well to undertake to rectify the trouble. Such an individual should be carefully questioned as to his general health, past illness and possible systemic causes of his derangement. It may be found that constitutional treatment is needed, but it is possible that these cases should also receive a course of eye calisthenics. Such treatment should include exercises of all the extrinsic muscles rather than the ciliaries alone, as great good may come from general increase of the ocular circulation. As a preliminary to office treatment, explicit directions should be given for home exercise. A series of eye movements should be performed in which the eyes are made to rotate to all positions of the orbit. The movements should be such that each muscle is alternately contracted and relaxed to its utmost. Thus the eyes may be rotated around the vertical axis as far as possible a given number of times, then around the horizontal axis, then in oblique directions. The ciliary exercise consists of holding fine print at the nearest point at which it can be read, then the eyes should be raised and fixed on an object across the room. By alternating these movements, momentarily fixing the near point, then the far point and repeating it a sufficient number of times, a stimulation of blood and nerve force is provided which frequently results in great benefit to the eyes with attendant increase of accommodation.

Office treatments consist of prism exercises for the extrinsic muscles, and also the use of minus spheres for ciliary gymnastics.

A good method is to place a presbyopic test card at sixteen inches, hold minus 2 D. spheres before the eyes and let the subject focus the fine print. The card should be moved forward to his near point, then back immediately to twenty inches; then forward again and back, repeating these movements of the card as many times as your judgment dictates. This exercise develops accommodation to a greater extent than convergence and it is this manner of increase in power that is required: an increase in the ratio rather than in the gross accommodation.

Recapitulation

To sum up our main points: Presbyopia results from hardening of the lens unless it is pathologic. If physiologic, it should be corrected by bifocals as soon as the amplitude becomes so low that half of it will be insufficient for routine duties. If pathologic, it should be corrected if possible by calisthenics and constitutional treatment. In undertaking this, care should be observed to avoid enlarging the ciliary muscle abnormally for fear of affecting the health of the eye. We determine the difference between pathologic and physiologic premature presbyopia by the muscle test at the near point. If the amplitude is low and the muscle test shows esophoria, it is physiologic presbyopia, but if with exophoria the low amplitude is pathologic.

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by

Lionel Laurance
London, England

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